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ELECTRIC HEAT IN THE PRODUCTION OF SILICON FERROALLOYS

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(Two different views exist among electrothermists on processes in mining thermic ore furnaces. M. S. Maksimenko, S. I. Tel'nyy, and G. A. Sisoyan among others, consider that arc conditions are essential for calcium carbide and silicon ferroalloys. S. A. Morgulev considers that they are not. Data and experiments are given below which should clarify Sisoyan's basic tenets as set forth in his article "Scientific and Technical Problems of Electrothermics," in Elektrichestvo, No 3, 1947. The present article is open to discussion.)

Up to the present, investigators into the large class of electric-smelting electrode-ferroalloy furnaces have not discovered to what extent these furnaces can be said to be of the arc type. The designer and the electrometallurgist are thereby deprived of a starting point for calculating the furnace parameters and the selection of a suitable electrical system.

To reduce losses when supplying a large amount of power to an electric furnace, heavy current techniques call for the highest possible voltage. This is also the main deduction from the "short network" theory of electric smelting furnaces. It has been pointed out more than once and recently mentioned again by G. A. Sisoyan (1) that: "In any case, one thing is quite clear today -- all our furnaces operate on the highest voltage tap existing in the transformers. It is thus evident that the principles involved require a certain clarification and scientific foundation."

However, the electrical engineering requirements here are insufficient. One must make clear what electrical conditions are required for the physicochemical processes of ferroalloy production with minimum heat losses.

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On the basis of the work of A. A. Baykov, M. A. Pavlov, S. S. Shteynberg and others, we showed (2) that the main condition for successfully obtaining, for example, a high percentage of ferrosilicon is the maintenance of a temperature of the order of 2,000°C in the reduction zone of the furnace. A. P. Lyuban considers that in addition it is important to prevent the reduced silica from passing into slag (3). He explains the impossibility of noticeable increasing the content of silicon in blast-furnace ferrosilicon by the difficulty of reducing silica from slag, although according to his measurements, the temperature in the focus of combustion reaches 1,900-2,000°C and 1,550-1,600°C along the hearth axis.

This raises the question of what electric conditions ensure maintenance of the necessary high temperature in the reduction zone of the furnace.

In the 1920's there was a tendency to deny the usefulness of creating arc conditions for smelting iron alloys. Miguet developed many furnaces designed to eliminate arcing conditions as a cause of "overheating of the metal and slag" and resulting in increased losses of elements such as manganese, silicon, etc. It was proposed that the furnaces should work with a small potential difference across the charge resistance.

Furnaces with movable electrodes can operate on charge resistance in the case when the electrode is immersed in an alloy having a high electrical resistance. This can be the case in certain slag processes, including some ferroalloy processes. In the slag-free process for producing silicon electroferroalloy, the liquid electroconductive alloy assists arc formation. It is, of course, possible by "quartzification" of a ferrosilicon furnace to achieve immersion of the electrode in the softened quartz glass before each arc dissipates, even when a fibrous-like slag is seen to adhere to the working end of the electrode. Then, in effect, all the phase power begins to be given off to the charge -- throughout its mass -- the charge hole in the furnace melts through rapidly, the lining, sometimes even the fettling of the bath fuses, but the reduction process ceases. "Slagging" the furnace is considered a gross technological blunder.

A furnace fitted with movable electrodes will always work without forming a melt of high electrical resistance, although with a relatively small dissipation of power in the arc. If, on the other hand, the potential difference when withdrawing the electrode from a solid charge is known to be less than the "ignition voltage," then, in the first place, the current will alter in jerks, and, in the second, there will be electrode breakage, short circuits, and similar occurrences.

The arc, when formed, immediately becomes the hottest place in the bath, which facilitates its repeated ignition due to thermal ionization of the gaseous interval. To regard a "small" arc as a transitional contact resistance is to indulge in camouflaging reality.

But what has been shown by experience in using Miguet furnaces? The Soviet ferroalloy industry in 1934-36 carried out trials of heavy-duty Miguet-Perran furnaces installed at the Zaparozh'ye plant. These furnaces were fitted with transformers with secondary phase voltages ranging from 25 to 57 v. At the lower steps, corresponding to the absence of an arc, attempts to accomplish technical fusion of ferrosilicon failed. Miguet himself recommended commencing at 38-40 v. Mastering the smelting process under these voltage conditions gave, in February-March 1934, a power consumption of 6,099 kw-hr/ton for a ton of 45% ferrosilicon (4). But at the same time, another ferroalloy plant operating at double the voltage reduced the power consumption to 5,280 kw-hr/ton. Following this example, the Zaporozh'ye plant began to work on the last step position of the change-over switch (57 v). After some time it was possible to raise the voltage at the furnace transformers by 4-6%, as a result of which the specific power consumption was reduced to 5,406 kw-hr/ton (4). Finally, at the suggestion of S. A. Margulev, the transformers of the Miguet-ZFZ furnaces were changed over to double secondary voltage.

50X1-HUM

In December 1936, one furnace, operating approximately on 82 v, had a power consumption of 5,093 kw-hr/ton when smelting 45% ferrosilicon. This was the convincing test which confirmed the indisputable usefulness of forming an arc in a ferrosilicon furnace.

The question arises, is it possible to determine the power dissipated in the arc?

M. S. Maksimenko (5) divides electric smelting production into two classes: (1) arc processes, for which the liberation of energy in the gaseous interval between the end of the electrode and the load $p > q$ where q is the energy liberated in the charge and scale, and (2) arc-less processes, for which $p < q$.

Considering all processes to be mixed, Maksimenko, in passing, assigned to the first class the production of calcium carbide, ferrochrome carbide, and ferrosilicon. Electrothermic engineers of the Dnepropetrovsk school of S. I. Tel'nyy (6) reached another conclusion: according to their calculations, oscillograms taken on Miguet furnaces showed that 60% of the total furnace current passes through the charge.

But, unfortunately, as G. A. Sisoyan writes, "Depending on the conditions in which the furnace arc is burning, the shape of the voltage curve may vary within very wide limits" (1).

Observations of ferroalloy furnaces show that the interpretation of the character of current and voltage curves is a complex task. For example, in April 1949, at one ferroalloy furnace where attempts were made to obtain a sinusoidal voltage curve, the secondary voltage was dropped from 100 to 80 v without altering the position of the electrodes in the bath. The current was then increased by lowering the electrodes; however, the voltage curve had a fairly pronounced peak each time. In May, the same alloy was being produced in another furnace at a voltage of 107 v and the voltage curve was indistinguishable from a true sinusoid. At a current amounting to 62-69% of the initial value, insignificant variations were observed on one side of the half-cycle, but when the current was further reduced to 30% of the initial value, the voltage curve was again a true sinusoid.

It is suggested that the presence and length of the arc can be established by lowering the electrode until a kick is observed in the current, due to the end of the electrode touching liquid or solid material. In the April experiments already mentioned, to obtain the nominal electrode currents at the 80 v voltage step, the electrodes were lowered as follows:

Phase I -- Load 52% of nominal, 30 mm

Phase II -- Load 60% of nominal, 15 mm

Phase III -- Load 61% of nominal, 20 mm

The increase in load was smooth, as is always the case in a ferroalloy furnace, if the process is proceeding normally and the furnace is warmed up. It should be pointed out that in a large ferroalloy furnace it is sometimes possible to observe the electrodes move up and down through a distance of the order of 1 mm. Thus experience shows that it would hardly be correct to draw conclusions concerning the length of the arc from the movement of the electrodes.

Hence, we cannot as yet determine what fraction of the power it is necessary and sufficient to liberate in the gaseous interval.

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50X1-HUM

However, the mere fact that an arc is present can easily be established. For this purpose one should stop loading the charge into the ferroalloy furnace and after some time the arc will become visible and audible. Alternatively, the electrode can be drawn out of the furnace and if an arc is present, it can be affirmed by observing whether its working end is the hottest part of the bath and whether the hottest gases are escaping from under the electrode.

Under production conditions it is desirable to ensure that the electrodes are immersed in the charge, and that the charge is loaded continuously in such a way that the arc will not be exposed; the heat losses of the charge hole will thereby be held to a minimum. Such was not the case at the Zaporozh'ye Ferroalloy Plant where the possibility of raising the voltage up to 114 v was not fully utilized, due to the increased heat losses which would have occurred through the charge hole. In spite of the high electrical efficiency of the Zaporozh'ye furnaces after a sharp reduction in current, the specific power consumption still did not compare with that of the furnaces at rival plants (see above), since in the latter furnaces the losses through the charge hole were lower (the "bath efficiency," according to our calculations, was higher by at least 5%).

The foregoing data is considered to be a more precise affirmation of Sisoyan's assertion (1) that the highest voltage step on the furnace transformers can only be used in those cases where an exposed arc will not result.

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50X1-HUM

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